SuperBIT - Suborbital imaging platforms for cosmological observations

Sub-arcsecond, wide-field imaging from the Super Pressure Balloon platform

William Jones (PI, Princeton), Tim Eifler (JPL/Caltech), Aurelien Fraisse (Princeton), Richard Massey (Durham), Barth Netterfield (Toronto), Jason Rhodes (JPL/Caltech)

The Artist formerly known as …

High Altitude Lensing Observatory

Jason Rhodes (Principal Investigator) Jeff Booth (Project Manager)

JPL: Paul Brugarolas, Ben Dobke , Eric Jullo, Kurt Liewer, Chris Paine, Michael Seiffert, James Wu **Caltech**: Richard Ellis, Sergio Pellegrino, Roger Smith , Harry Teplitz(IPAC) **Wallops Flight Facility:** Raymond Lanzi, David Stuchlick, **NOAJ(Japan):** Satoshi Miyazaki **ETH Zurich:** Adam Amara, Simon Lilly, Udo Wehmeier **Edinburgh (UK):** Tom Kitching, Richard Massey, John Peacock **Durham (UK):** Ray Sharples, Paul Clark, Richrd Meyers **UKATC:** David Lunney, David Henry, Naidu Bezawada **UChicago:** Ali Vanderveld **e2v**: Roger Pittock

HALO: The High Altitude Lensing Observatory (idea as in ~2008)

2011-2014

Single night flights; 2x2 detector array;N2 cooling, standard balloon

Stage 1

2012-2016

Multiple flights of ~100 days; 50 CCDs; ULDB; dark energy constraints

Stage 2

This clearly did not happen… so why is this now a good idea?

The idea was always good…

Overwhelming advantage in the near UV (λ < 400 nm)

Significant advantage in the near IR (λ > 900 nm)

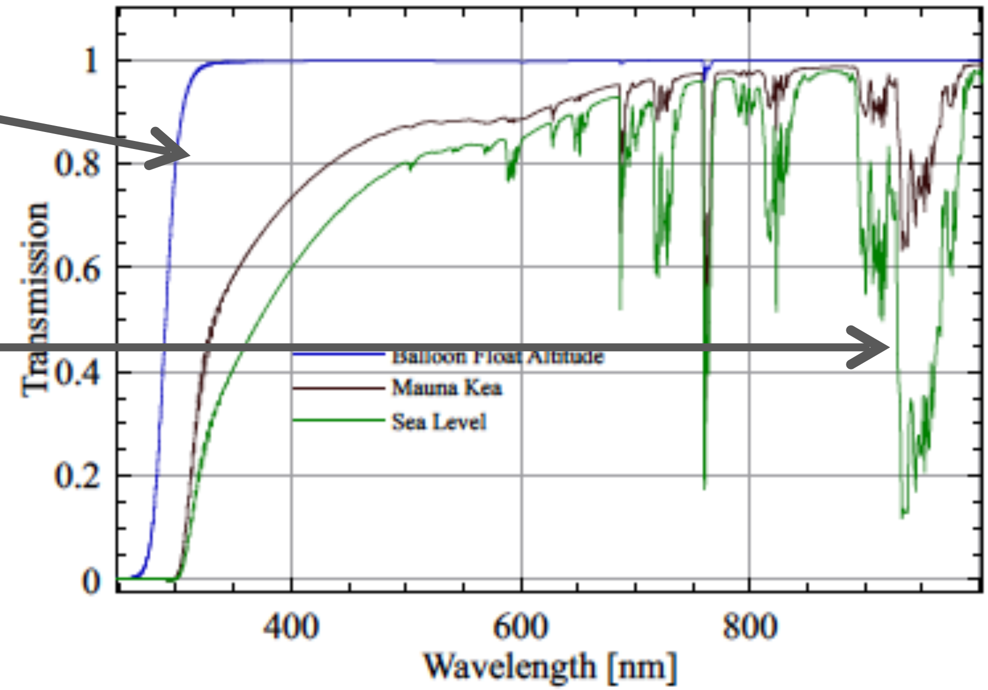


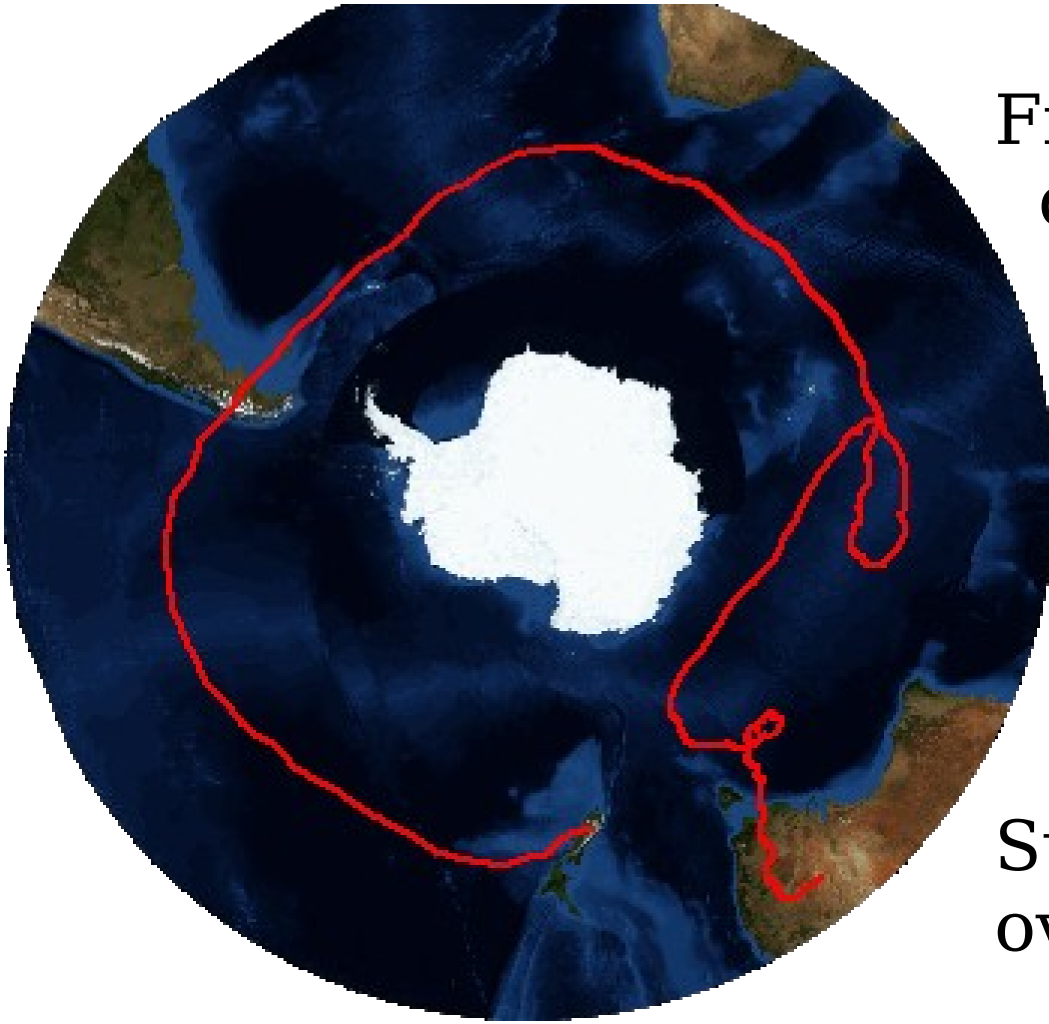
Figure 1: Atmospheric transmission as calculated by MODTRAN4 [2]. Reduced air column, and decreased pressure broadening provides significantly reduced atmospheric absorption at float, particularly in the blue and near-UV bands.

- **Diffraction limited resolution**
- **Space-like sensitivity**
- **Enormous imaging speed in the Blue/UV**

Main Argument: It's cheap

The idea was always good…so why now?

ULDB mid latitude flights are happening



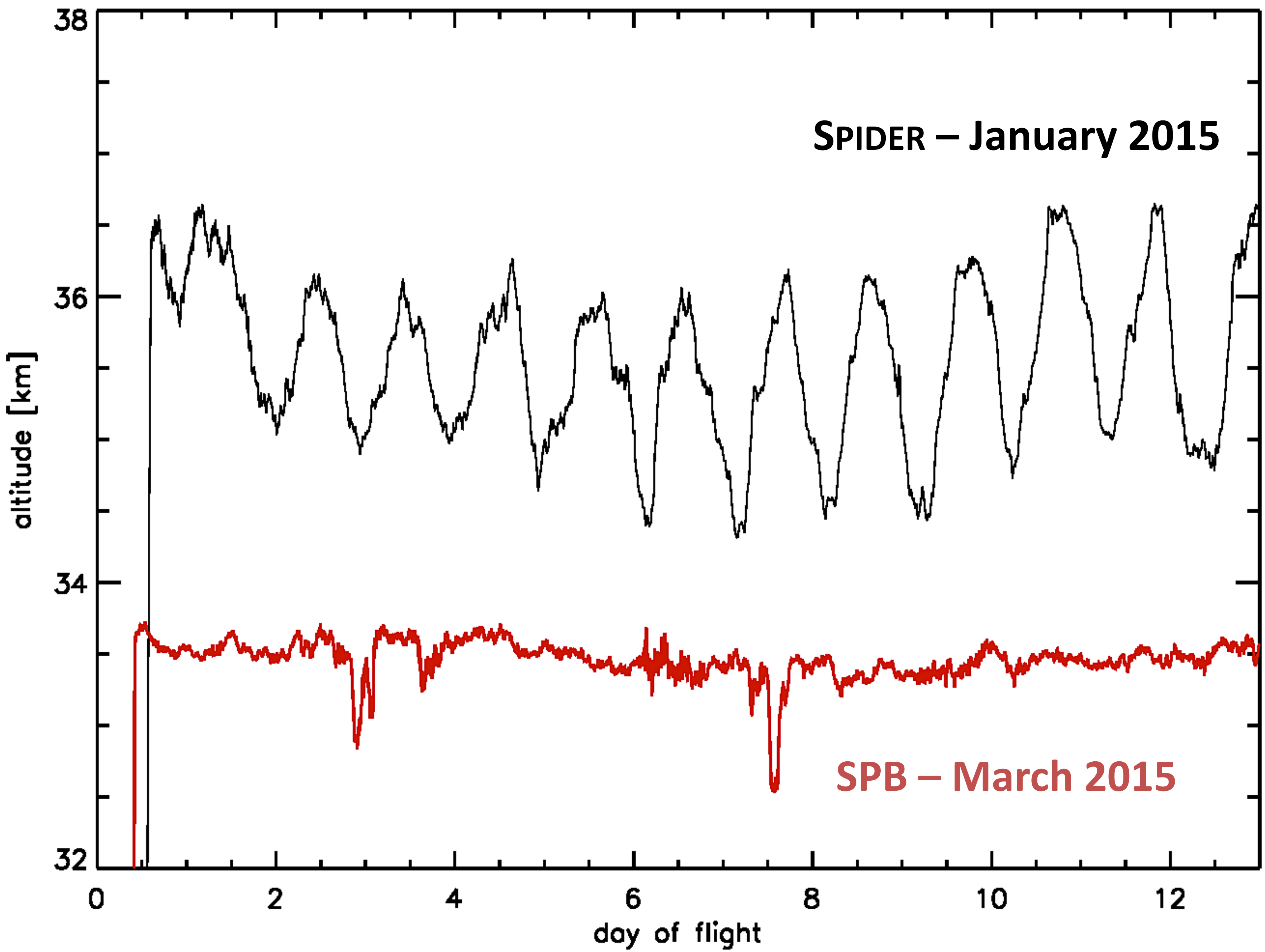
First Mid-latitude long duration balloon flight this spring

33 day flight.

Excellent altitude stability

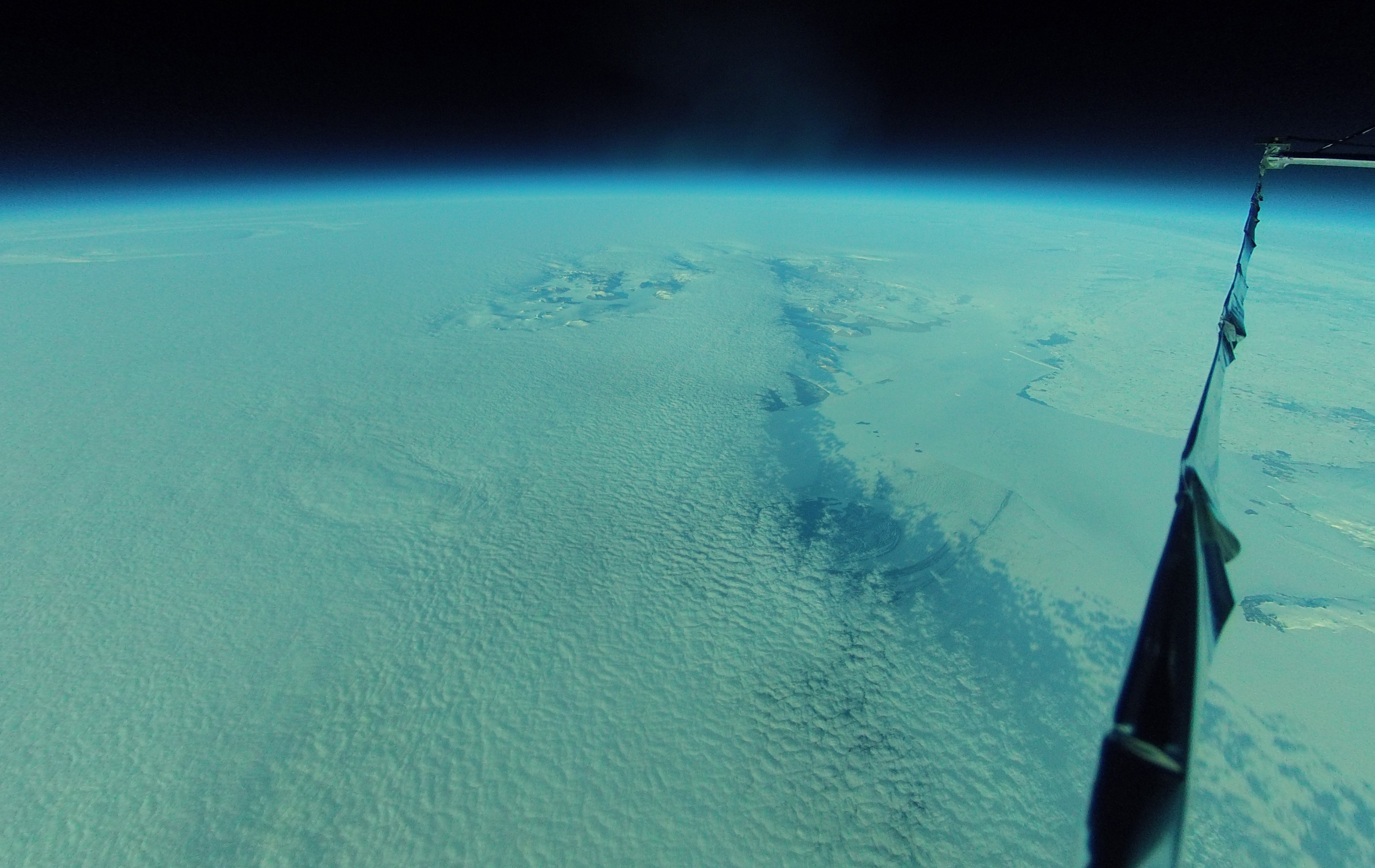
Started to loose pressure over Australia.

2500 lb science payload.



SPIDER – January 2015
SPB – March 2015
altitude [km]
day of flight
38
36
34
32
0
2
4
6
8
10
12

Antarctic LDB: Sun above the horizon 100% of the time.
Daytime sky-glow is significant, show stopper in the near UV/IR



Mid Latitude ULDBs:

≈100 day flights, 6-12 hour nights

A new mid-latitude capability has opened up access to long duration night flights in this environment

SuperBIT mission - launch 2017/18

Science cases: Cluster Weak Lensing
Clusters in their filamentary environment,
DES overlap and calibration ideas

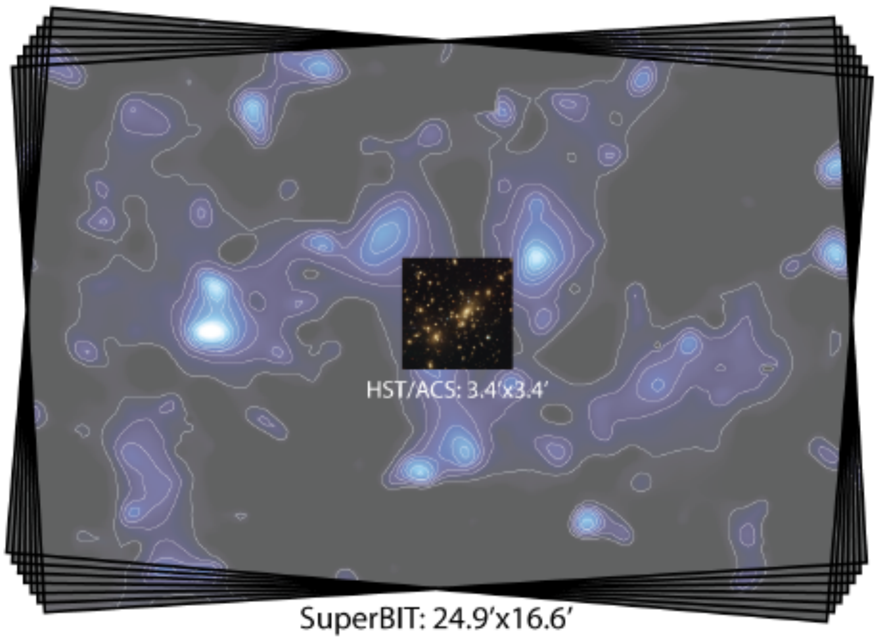
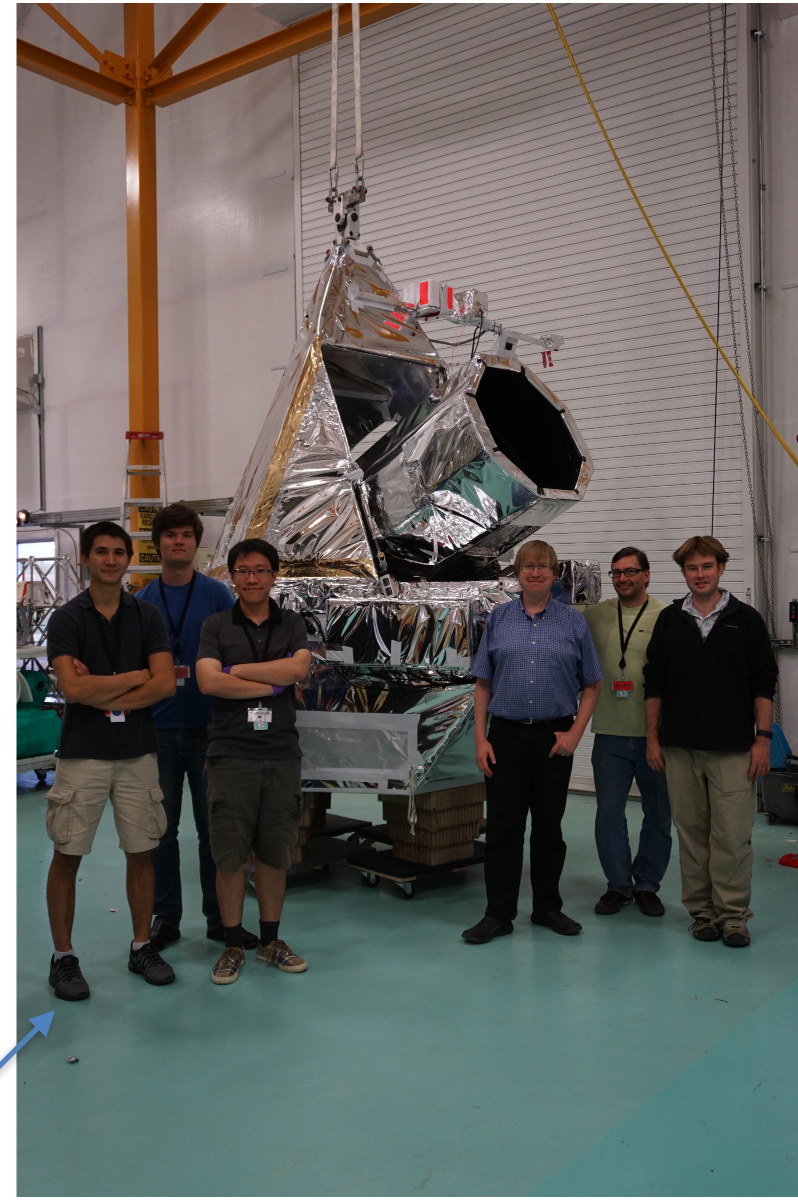


Figure 3: SuperBIT's field of view is 36 times bigger than that of the largest camera on HST. This will allow us to study entire (even nearby) galaxy clusters in a single pointing – including their outer environment and attachment to the cosmic web – without any need for mosaicking. The center square shows an HST image of Abell 2218; surrounding background shows a weak lensing map of the cosmic web from an HST mosaic.

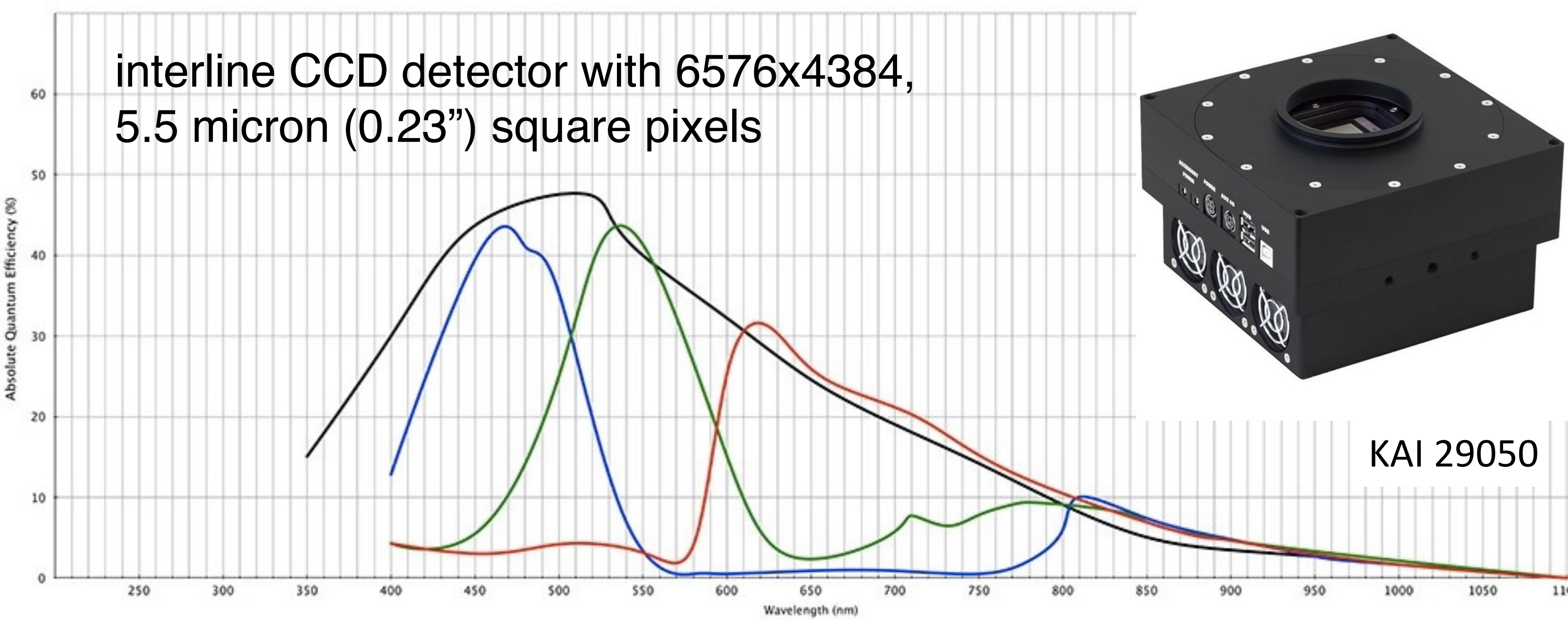


BIT test flight

SuperBIT - 0.3’’ resolution imaging over a 0.4 field of view in five bands between 300 and 1000 nm with sensitivities exceeding 24th magnitude (5 point source).

Band	λ_c [nm]	$\Delta\lambda/\lambda$	Band Start	Band Stop	Nyquist [pixels/PSF]	M_{phot}	N_{exp}
u	360	0.28	300	400	0.67	28	8
u'	393	0.38	300	450	0.73	7	3
g	478	0.31	400	550	0.89	4	3
r	619	0.26	550	710	1.15	7	6
shape	666	0.53	550	900	1.22	–	3
ACS f814w	783	0.29	702	930	1.46	25	20

interline CCD detector with 6576x4384,
5.5 micron (0.23”) square pixels



Problem 1: Pointing stability

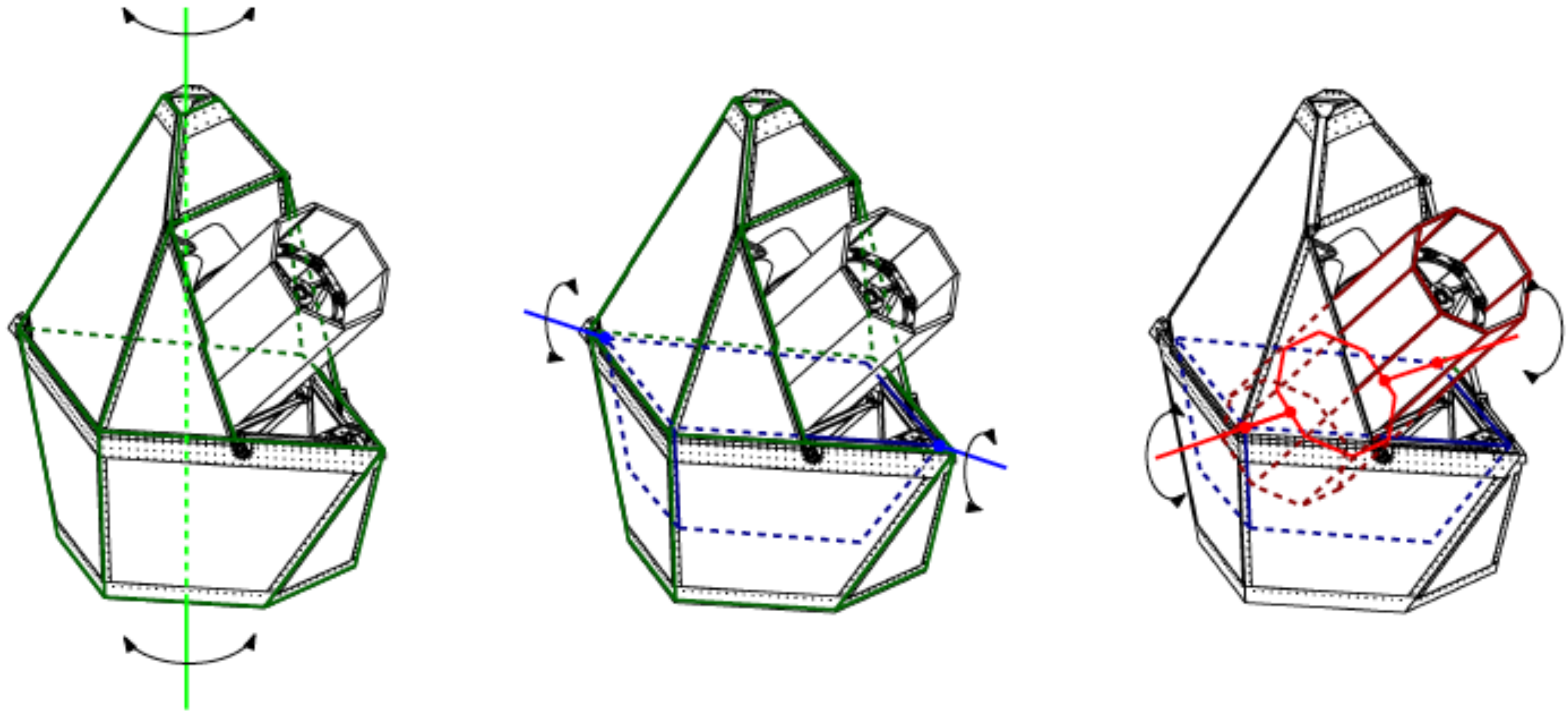
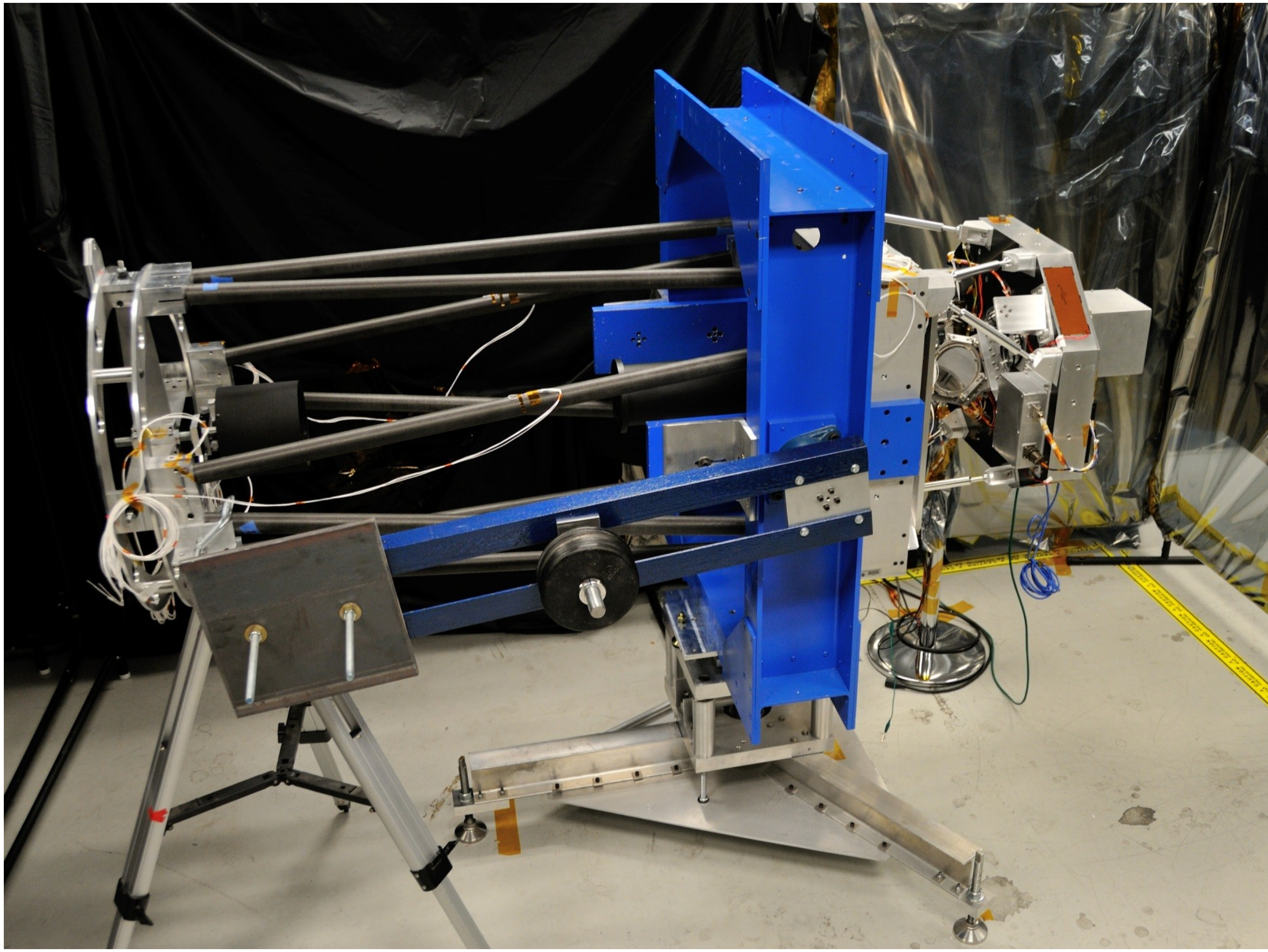


Figure 5: The SuperBIT gondola's Yaw/Roll/Pitch mount. The attitude of the telescope is controlled in three nearly orthogonal axes as required by SuperBIT's wide field. The outer frame is controlled in yaw (green), the middle frame is controlled in roll (blue) and the inner frame is controlled in pitch (red).

Gondola achieves 1'' stability

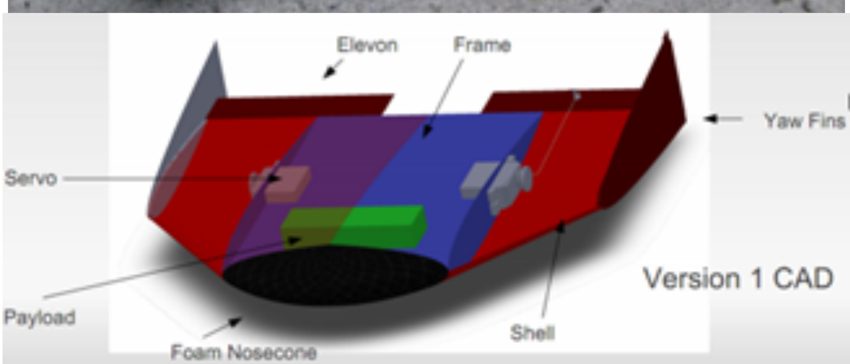
Problem 1: Pointing stability

- Fast steering mirror (~60Hz) to stabilize image
- Requires bright guide stars
- Sunrise has achieved <50mAs



Problem 2: Data Recovery…

Idea AIRS: Automated Information Retrieval System



- JPL summer student project (Mentor Jason Rhodes)
- GPS guided autonomous glider
- Can return a solid state hard drive from balloon altitude to ground
- Simple technology
- Cheap (~$1k)
- Safe (meets all FAA regulations)

- Had only done low altitude glide tests (~10 meters)
- More development done this summer

- Could retrieve 1 TB during every overpass (every 2-3 weeks)

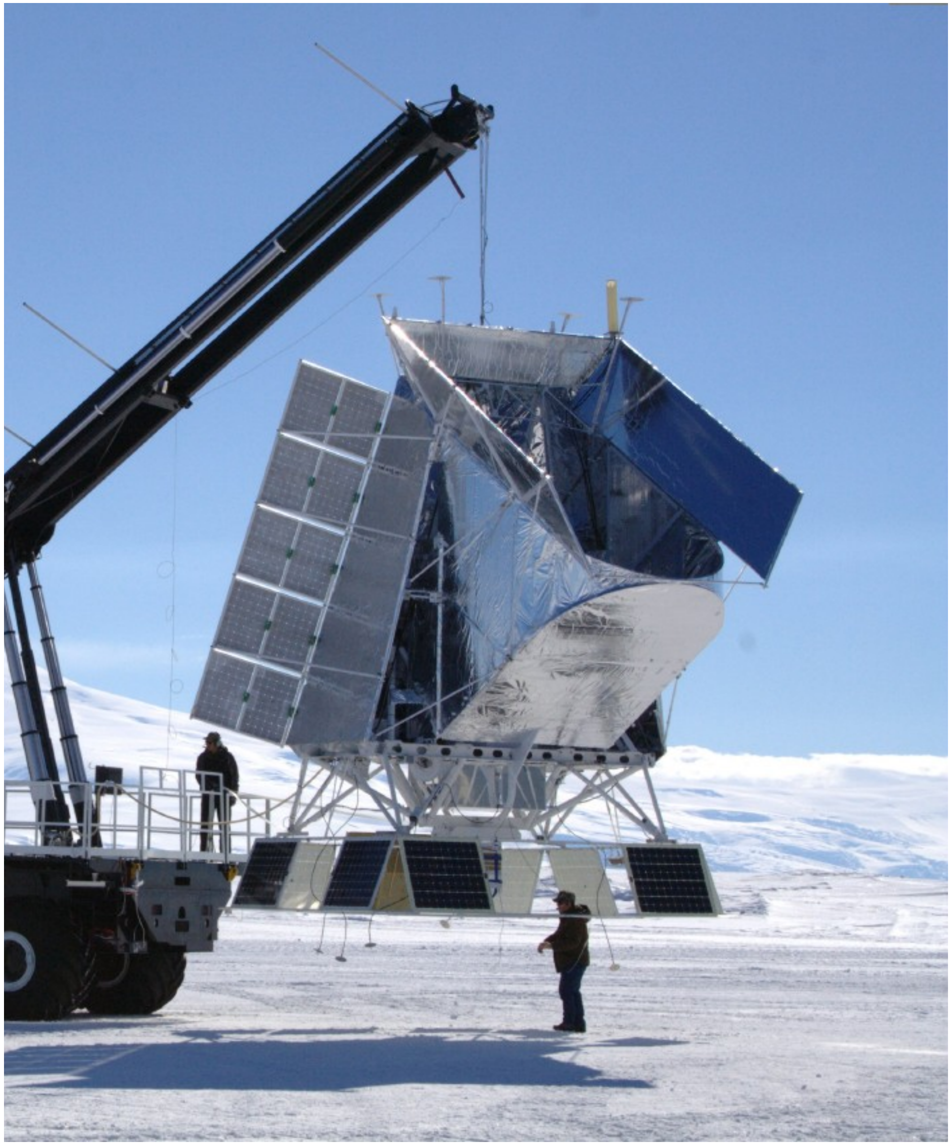
Future

Mirror Size

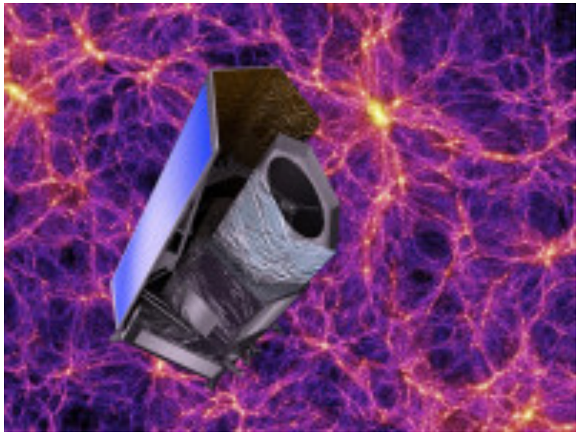
BLAST has flow a 2m primary.

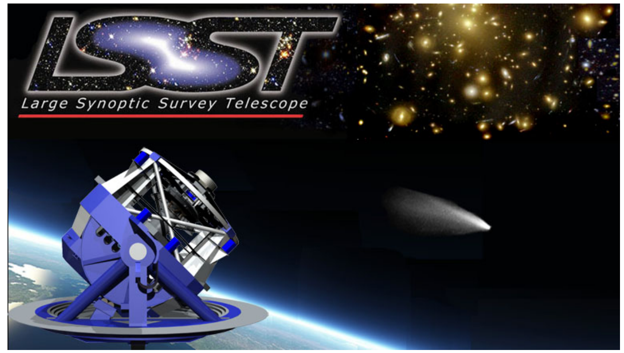
The Gondola can accommodate up to A 2.5m mirror.

A very fast telescope so very sensitive to thermal expansion.



Synergies





Euclid:
Photo-zs,
Blue+UV observations

LSST:
Blue+UV observations, photoz
Shapes, blending

WFIRST
photo-z, Blue+UV
Optical bands

Quick performance comparison:

Euclid		1 future Balloon mission
3	day/night	1
3.5	100 d/year	1
0.57 deg^2	camera FoV	??
1.2 m	mirror size	??
1G USD	money	~100 x cheaper

Multi-Balloon Campaign as a far-future missions

- Near-Space quality imaging
- advantages in UV and IR transmission
- Reusability (unclear but > 0%)
- Risk minimization; if something goes wrong, no disaster
- Modularity (update detectors; fly spectrograph)

How much science return for e.g. Flagship mission money? Answer early next year…